Executive Summary of Managed Wetlands Treatment System Testing

ES.1 Introduction

This report provides a summary of six quarters of testing (July 1999 – December 31, 2000) at the Everglades Nutrient Removal (ENR) site for the Managed Wetlands Treatment System (MWTS) project. The first three quarters comprised the calibration/baseline testing period. The fourth, fifth, and sixth quarters comprised the period of experimental operation.

This section is a synopsis of the information described in the final report of the Managed Wetland Treatment System Project. The reader is encouraged to refer to the full report for specific numeric details of the trends summarized here.

The subsequent sections of the report cover the following topics:

Section 1—Introduction
Section 2—Materials, Methods, and Descriptions of Chemical Treatment Units
Section 3—Meteorological Data
Section 4—Results of Testing and Evaluations
Section 5— Marsh Readiness and Ionic Conditioning
Section 6—Summary and Recommendations

For the reader's convenience, an 11 x 17 foldout page is provided at the back of this document and at the back of the appendices volume that accompanies this document to provide the reader easy reference to the full set of abbreviations and naming conventions for this report. By unfolding the page the reader can have a ready reference for all abbreviations and acronyms while reading.

ES.2 Purpose

The general purpose of this project was to test the ability of an MWTS to achieve Everglades Forever Act goals of a discharge with a total phosphorous (TP) concentration not greater than 10 parts per billion (ppb). This was a research, demonstration, and optimization project with the objectives of obtaining nutrient removal performance data and operational experience sufficient to:

- Perform a preliminary evaluation of the technical and environmental feasibility of using a MWTS for phosphorous (P) removal at either basin or farm scales.
- Compare this technology with others under consideration
- Provide design recommendations for a full-scale MWTS.

In concept, a full-scale MWTS must be able to consistently reduce water column TP concentrations to the ultimate TP target by chemical precipitation and reaction of phosphorous, and adsorption of phosphorous followed by solids storage/retention in treatment basins. Effluent from this treatment unit would be delivered to a receiving wetland to complete phosphorous polishing and accomplish ionic stabilization to ensure the marsh readiness final outflow water. The wetland component of the MWTS may be either a constructed system or a natural one, depending on whether the technology is applied at the farm, sub-basin, or basin level.

The MWTS testing addressed three general research objectives:

1. Achieve TP concentration of 10 ppb or less by chemical treatment. Characterize the relationships between the efficiency of TP removal in an MWTS and several key design parameters, such as influent TP concentration and mass-loading, coagulant selection and concentration, polymer selection and concentration, hydraulic loading rate, solids contact system solids retention time (SRT), solids handling and disposal, effects of solids aging on long-term phosphorous removal.
2. Determine the effective range of treatment overflow rates and SRTs for chemically treated Everglades Agricultural Area (EAA) runoff with selected P concentrations and loads that achieve a target P removal efficiency for the chemical treatment component of the MWTS. Quantify solids overflow from the chemical treatment unit into the wetland unit, and from the wetland to downstream waters.
3. Use a paired watershed analysis and other statistical techniques to evaluate if outflow from an MWTS that receives chemically treated water differs qualitatively from outflow of constructed wetlands that only receive EAA runoff water. Identify whether the outflow from a MWTS is marsh ready, as defined by Florida Department of Environmental Protection (FDEP) procedures. Assess the ability of the wetland unit to provide ionic conditioning at relatively high hydraulic loading rates.

ES.3 Experimental Design and Methods

Testing of chemical treatment followed by marsh conditioning was initiated at the Everglades Nutrient Removal Project (ENR) in three cells of the North Test Cell (NTC) site and at two cells in the South Test Cell (STC) site.

- North Test Cells

– NTC-FeC1	NTC-FeCl	Iron (Fe) treatment cell
– NTC-Control	NTC-Control	Control cell
– NTC-PACL	NTC- PACL	Aluminum (Al) treatment

- South Test Cells

– STC-Control	STC-Control	Control cell
– STC-PACL	STC-PACL	Aluminum (Al) treatment cell

There are several naming conventions of which the reader should be immediately aware:

- "Inflow" refers to raw water inflow to the system. During the calibration period inflow water entered each wetland. During the experimental period the inflow continued to enter the control cell directly, while in the treatment cells the water was chemically treated prior to entering the wetland. Thus for the treatment cells this is the inflow to the chemical treatment plant during the experimental period.

- “Plant outflow” refers to outflow from the chemical treatment plants into the marsh, and refers therefore only to treatment cells during the treatment period. Sampling of the plant outflow was performed at the plant outflow only during the treatment period.
- “Marsh outflow” and “final outflow” both refer to the sampling point of the final discharge from each wetland cell.

During the calibration period all water flowed from a single upstream storage pond directly into each cell. During the experimental period the water supply to the NTC and to the STC cells was routed first to a splitter box, where an equal amount of water was sent to each of the cells (three in the NTC and three in the STC). In the NTC, two of the cells were preceded by a chemical treatment plant (NTC-FeCl and NTC-PACL), referred to by that name or simply “plant.” In the STC one chemical treatment plant (STC-PACL) was operated, and the remaining two cells were treated as control cells (NTC-Control and STC-Control). One of the two control cells at the south site, STC-5, was eliminated from sampling early in the experimental period for efficiency and experimental design purposes.

Each chemical treatment plant consisted of, and water flowed through, two 20-gallon rapid mix tanks, a flocculation tank, a settling plate tank, and sludge storage tank in that order. Inflow water was introduced into the first rapid-mix tank. Coagulant and any pH adjustment chemical were also introduced into the first rapid-mix tank, and the polymer into the second. After mixing, the water flowed into a flocculation tank and then passed through a multi-plate clarifier for settling. The clarified effluent flowed by gravity to the top of a sludge storage tank, entering through a diffuser near the water surface of the tank, and flowed out of the same tank through a pipe located just under the water surface of the sludge storage tank on the opposite side from the diffuser. The sludge from the clarifier was piped into the bottom of the sludge storage tank.

Water quality samples were regularly collected on a variety of schedules from the inflow, plant outflow, stations at 1/3 and 2/3 of the distance from the plant outflow station to the marsh outflow, and the marsh outflow. The water quality sampling for field and laboratory parameters followed the schedule defined in the MWTS research plan and work plan.

Data analyses included the following:

- Hydrologic balances
- Water quality trends throughout the experimental period
- Mass balances for phosphorous and nitrogen species
- Paired Watershed Analysis of phosphorous species Total Phosphorous, Total Dissolved Phosphorous, and Soluble Reactive Phosphorous (TP, TDP, and SRP), total Kjeldahl Nitrogen (TKN), and alkalinity, aluminum, calcium, chloride, iron, magnesium, sulfate, total dissolved solids (TDS) and total organic carbon (TOC).
- Statistical and visual-display comparisons of a suite of mineral concentrations in the several wetlands used in the experiment. Single species and multi-parameter comparisons were made.

ES.4 Summary of Results

ES.4.1 Everglades Nutrient Removal Test Cell Experimental Results

Hydrologic Regime

The target operating depth for the Test Cells is 0.33 meters (m) and the target hydraulic loading rate (HLR) was 10 centimeters per day (cm/d). For the treatment period water depth in the test cells ranged from 0. 3 to 0.5 m. Quarterly average HLRs were in the range of 7 to 10 cm/d for the NTCs, and 7 – 11 cm/d for the STCs.

Water Balance

A water balance for each test cell was calculated from the measured and estimated inflows, and changes in storage volume. Because the test cells were lined, seepage loss was assumed to be zero. Marsh outflow was reported as the difference between the sum of the inflows and changes in storage volume. Calculated in this fashion, cumulative monthly inflow and outflow closely tracked the target water balance.

Water Quality

The chemical treatments pilot units (two in the NTC and one in the STC) began operation in February-March 2000 and operated through the last three entire quarters (April through December) of 2000. Changes in constituent concentrations of the inflow measured at the marsh outflow can be summarized:

- NTC-FeCl and NTC-PACL treatments reduced TP, total particulate phosphorous (TPP), SRP, TDP, dissolved organic phosphorous (DOP), total nitrogen (TN), TKN, organic nitrogen (org-N), and TOC concentrations relative to the control. Color was reduced in both NTC and STC aluminum (Al) treatments.
- TPP in the treatment plant outflow was typically removed in the wetland portion of each system.

Phosphorous

Throughout the treatment period, NTC raw water inflow TP concentration ([TP]) was greater than that from the respective wetlands outflows. This trend was often reversed for the STCs for treatment (STC-PACL) and control (STC-Control) cell . For both locations inflow [TP] was relatively evenly split between particulate and dissolved fractions. Inflow [TP] was in a range of 40 to 230 ppb at the NTCs and 20 to 180 ppb at the STCs. Both NTC-FeCL and NTC-PACL treatment wetland outflow [TP] were lower than that of NTC-Control. Iron treatment resulted in a 40 to 80 percent reduction and aluminum yielded a 50 to 85 percent reduction. The [TP] and [TPP] concentrations fell across the length of the wetland for both control and treatments (FeCl and PACL) at the NTC. This result indicates that particulate P from the respective chemical treatment outflow was removed at the head of the wetland. Marsh outflow [TP] at STC-PACL was typically 10 percent to 20 percent lower than for STC-Control. Exhibits ES-1, ES-2, and ES-3 provide graphical summaries for TP for the treatment period at ENR, highlighting the last 4 months of testing.

EXHIBIT ES-1

(A) Time series of TP inflow and outflows for NTCs over treatment period April through December 2000. (**B**) TP time series for final 4 months of treatment period.

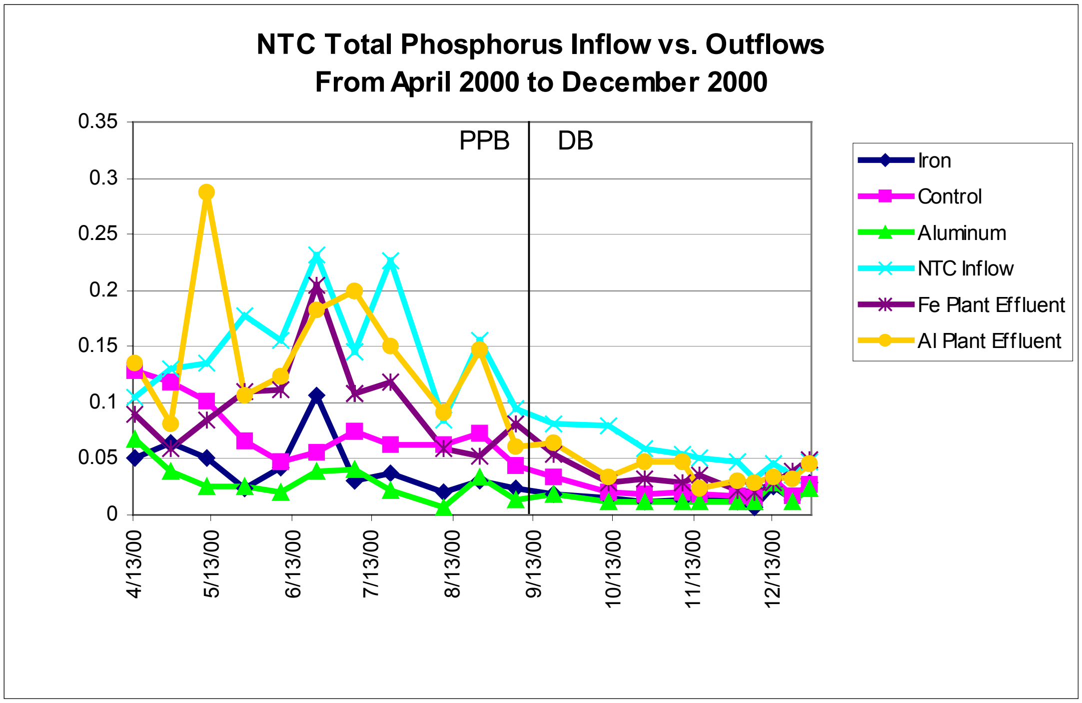


Exhibit ES-1 (A)

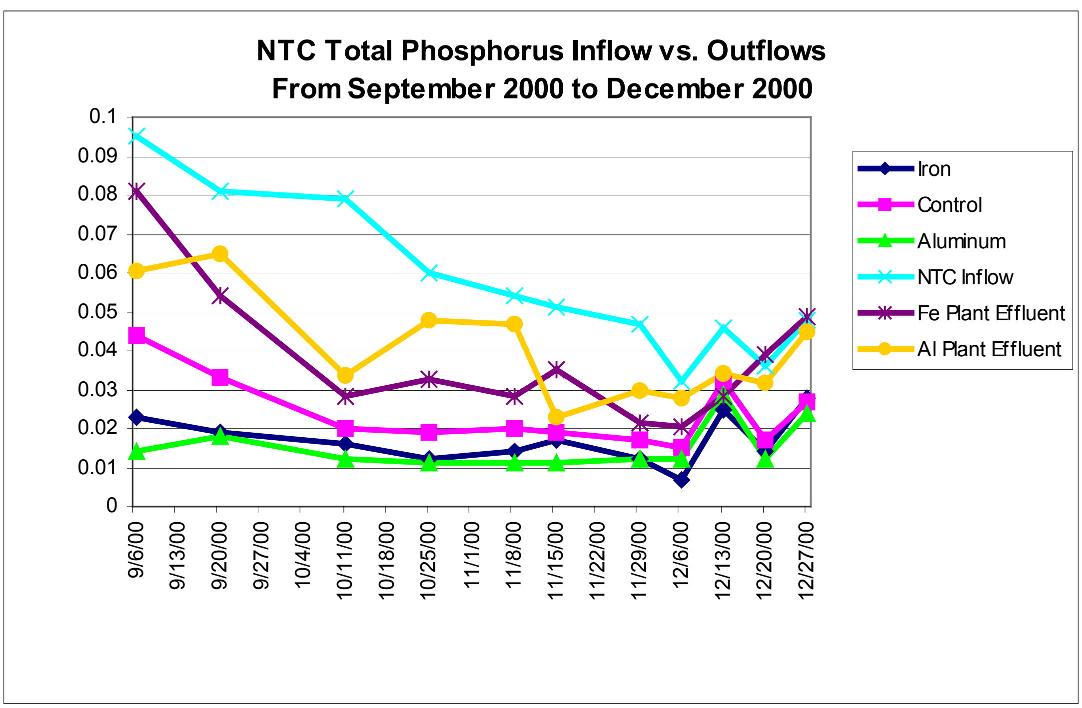


Exhibit ES-1 (B)

EXHIBIT ES-2

(A) Time series of TP inflow and outflows for STCs over treatment period of April through December 2000. **(B)** TP time series for final 4 months of treatment period.

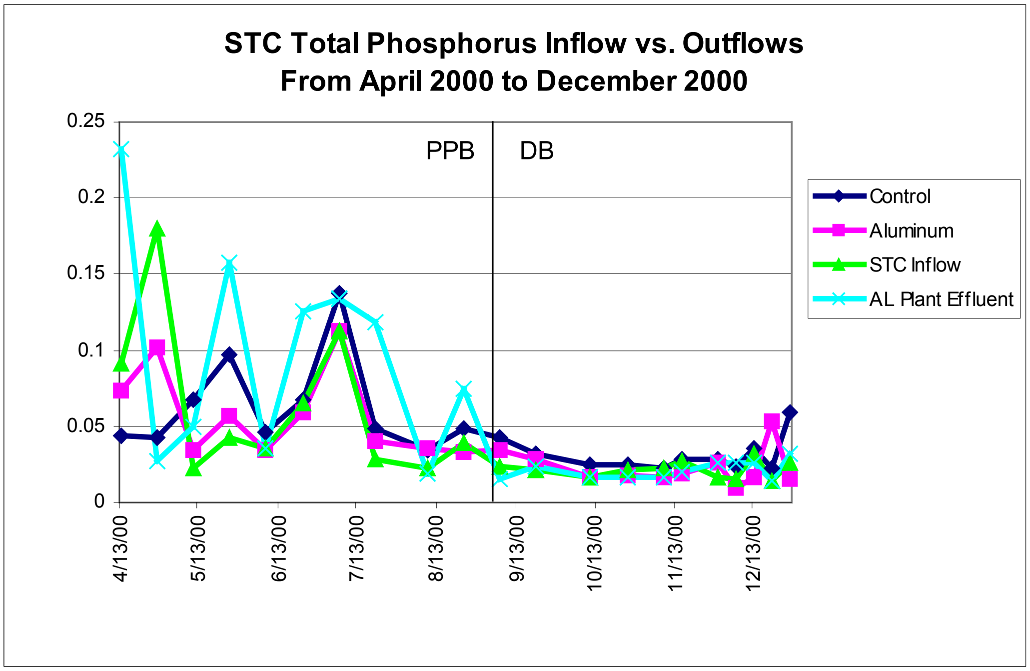


Exhibit ES-2 (A)

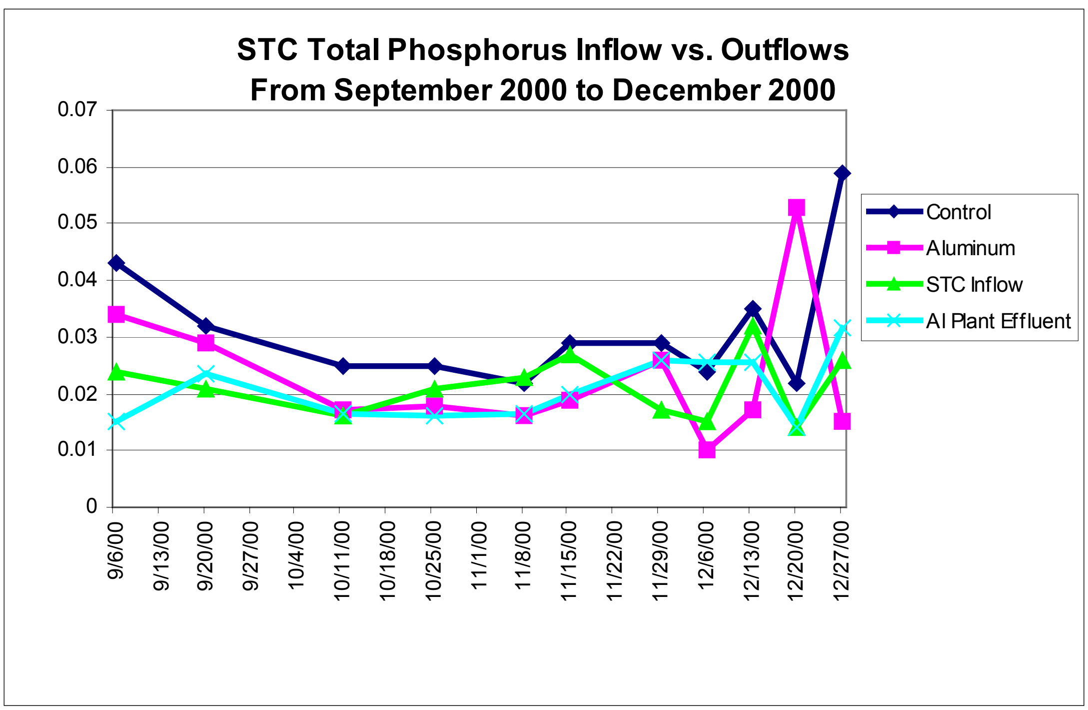
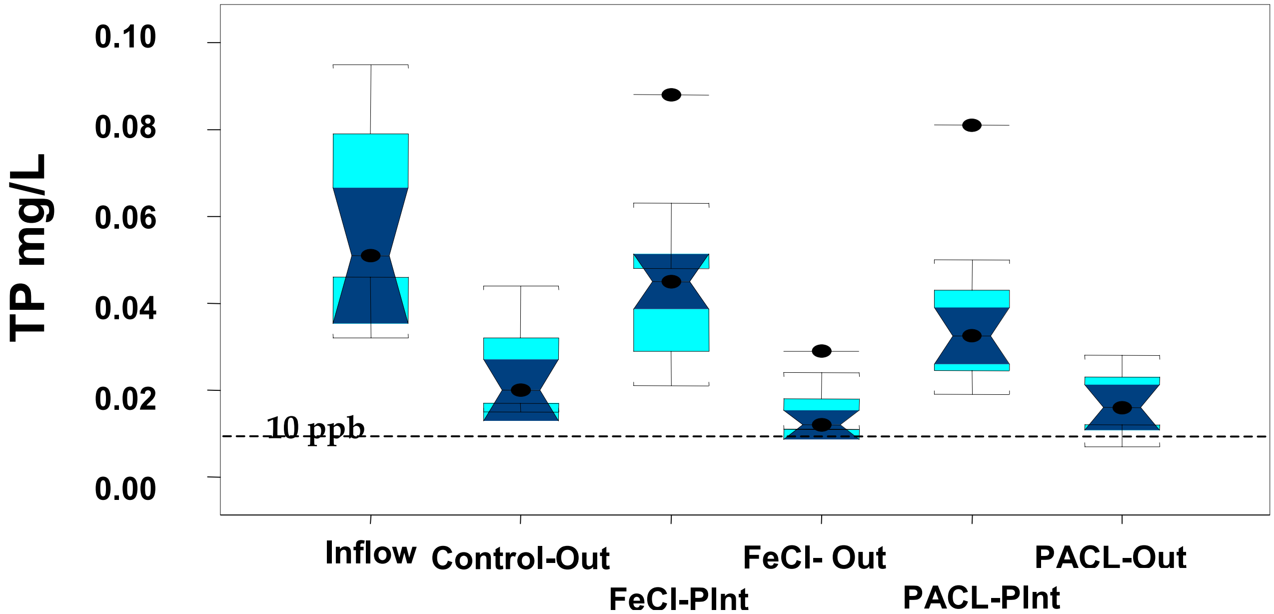
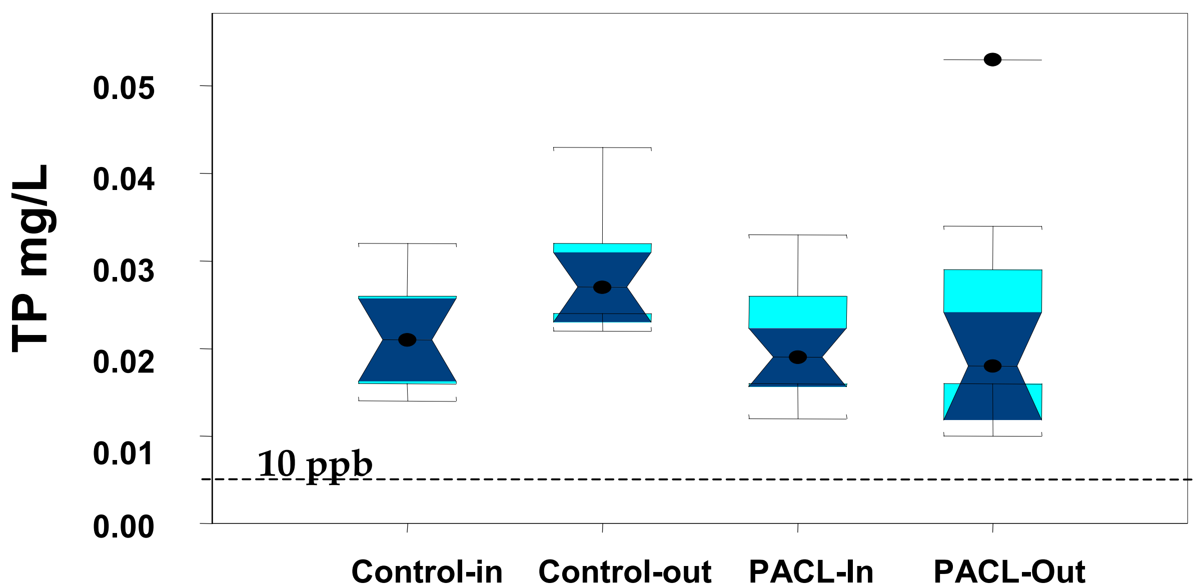


Exhibit ES-2 (B)

EXHIBIT ES-3
Boxplot summaries of TP inflow and outflows over final 4 months of testing for NTCs (top) and STCs (bottom).





Figures ES-2 and ES-3 show that over the final phase of testing, NTC-FeCl and NTC-PACL performed close to the 10 ppb target for TP. The TP average of seven of the last 10 samples of wetland outflows was 11.5 ppb, the median TP value over the period was 16 ppb. For the iron treatment the median TP value was 15 ppb.

Nitrogen

The average raw water inflow [TN] was slightly lower at the STC cells than that of NTC cells. TN inflow and wetland outflow concentrations were approximately equal for the control cells (NTC-Control, STC-Control). NTC and STC treatment cell (NTC-FeCl and PACL, and STC-PACL) results showed a treatment effect for nitrogen: lower marsh outflow [TN] for the treatments as compared to the controls. Nitrogen wetland outflow nitrogen concentrations were reduced to a greater extent in NTC-PACL than in the NTC-FeCl.

Other Water Quality Parameters

Inflow and marsh outflow concentrations were approximately equal in all cells for total suspended solids (TSS), magnesium, and calcium. Other water quality trends included:

- Sulfate—NTC treatments (both iron [Fe], PACL) slightly reduced outflow sulfate concentrations compared to the control, NTC-Control. Comparison of STC-Control and STC-PACL were inconclusive.
- Color—Chemical treatments at both the northern and southern sites reduced color relative to the control. At the north site, the PACL treatment resulted in lower color values than the FeCL treatment. Color did not change significantly in NTC-Control and STC-Control.
- TOC—Results for the sixth quarter are similar to those for color, the chemical treatments at both locations resulted in lower outflow [TOC], compared to the controls. At the NTC sites the aluminum treatment (NTC-PACL) lowered TOC values more than the iron treatment (NTC-FeCL).
- Dissolved silica—Results follow the pattern noted for color and TOC. This indicates a reduced concentration for outflow as compared to inflow for NTC-PACL, STC-PACL and NTC-FeCl treatments.
- Fe, Cl—The ferric chloride treatment (NTC-FeCl) resulted in higher outflow concentrations of iron and chloride than either the control (NTC-Control) or the aluminum treatment (NTC-PACL). At the remaining test cells the inflow and outflow values are approximately equal for iron and chloride.
- Aluminum – Aluminum concentrations (sampled monthly) in the NTC-PACL marsh outflow were greater than that of NTC-Control and the raw inflow water. The first marsh sampling point (1/3) station in all NTC cells, including the NTC-Control, had a significantly higher average concentration of aluminum. Aluminum concentrations in STC-PACL were highest at the plant outflow and fell in the marsh. Average final outflow concentration was not significantly different than that in the raw water inflow. NTC-PACL outflow [Al] increased over the treatment period.

- Hardness—Average NTC outflow hardness tended to be slightly lower than the average inflow value. The trend was most pronounced in the Fe treatment (NTC-FeCl). No trend was discernable in the STCs.
- Alkalinity. —The alkalinity inflow/outflow relationship varied by sample date in all cells except STC-PACL (Al treatment) where outflow alkalinity was distinctly lower than that of the inflow.

Mass Balance

Phosphorous. The general P removal trends observed over the treatment period at the ENR test cells remained consistent over the final four months of testing. The NTC-FeCl, NTC-Control, and NTC-PACL treatments removed 80 percent, 55 percent, and 85 percent of influent P load, respectively. Month to month results were quite variable for the STCs, but in keeping with results from previous quarters there was a net export of P, with average removal rates -35 percent in the STC-Control cell and -10 percent in the STC-PACL treatment cell.

Inflow phosphorous concentration decreased over the period September 2000 to the end of the December 2000.

Nitrogen. A treatment effect was apparent in NTC-FeCl and NTC-PACL. TN removal averaged 35 percent for the iron treatment cell (NTC-FeCl), 60 percent for the aluminum treatment cell (NTC-PACL), and 10 percent for the control cell (NTC-Control). The quarterly mean mass removal rate was in the range of 10 percent for STC-PACL but was negative for the STC-control.

ES.4.2 Chemical Treatment Pilot Plant Operation

During the fourth quarter of testing (April – June 2000), it appeared that the chemical treatment systems at both sites were not reducing phosphorous to the target levels predicted by previous jar-testing. A focused investigation of pilot plant operation was carried in out early May. Based on that investigation, adjustments were made to plant operations. Changes in flocculating agent and polymer injection rates, in the operation of the mixing tanks, and of the operation of the flocculating tank were made. By early July it was clear that even with the operational adjustments made in May and June, the pilot plants were still not producing the low levels of TDP expected by stoichiometric calculations, even at extremely high coagulant doses. Some of the laboratory analysis results began to be questioned at this time. In September a different laboratory began providing phosphorous analyses. After the laboratory switch, many of the chemical plant outflow TDP samples were reported at less than 10 ppb. TP concentrations remained slightly higher than the target concentration. Dramatic reductions in plant outflow TSS concentrations occurred after internal plant recirculation was stopped in early September. The recirculation was causing disruption of the sludge in the bottom of the tank, which resulted in TSS entering the plant outflow pipe. Nevertheless, plant outflows [TP] after that change were typically in the 20 to 50 ppb range at the NTC plants, and around 20 ppb at the South plant. This was an artifact of floc moving past the settling plates, and passing through the upper water column of the sludge storage tanks into the plant outflow. The carryover was likely due to the high hydraulic loading rates on the settling plates, which, while within the theoretical performance range for the plates, were exceeded in practice.

By the fifth quarter the chemical plants were producing TDP values operating as expected from earlier jar testing, with TDP concentrations typically less than 10 ppb. It is probable that this was the case throughout most of the study; erroneous lab data disguised actual performance, and prevented the investigators from seeing the real effect of operational changes over time.

ES.4.3 Paired Watershed Experimental Design Analysis

Paired Watershed Analysis (PWA) is a statistical technique that tests chemical concentration changes in discharges from the cells as a result of chemical treatment and wetland conditioning. Linear regression and analysis of covariance (ANCOVA) were used to statistically model and compare water quality differences in control and treatment cells. TP, SRP, TDP, TKN, and several other chemical parameters were modeled. The analysis provided statistical evidence of change, or lack thereof, for the various constituents by comparing statistical predictions against observed data.

NTC treatments (NTC-FeCl and NTC-PACL) removed significantly more phosphorous and nitrogen than the NTC control cell, and allowed a quantification of the degree of the effects. The PACL treatment cell showed a larger reduction in TP (about 30 percent) than occurred in the ferric chloride (iron) treatment cell (about 20 percent) compared to the calibration (pre-change) period of operation. SRP results were somewhat less distinct, and TDP dynamics were not well modeled using either Ordinary Least Squares or Robust (non-parametric) regression techniques.

TKN was significantly reduced in both NTC and STC treatment cells (NTC-FeCl and NTC-PACL, and STC-PACL). Alkalinity changed only slightly, while TDS were increased by 14 percent in the iron treatment (STC-FeCl) cell marsh outflow. Sulfates were reduced in both NTC-FeCl (-14 percent) and NTC-PACL (-20 percent) , but were little affected in STC-PACL compared to the STC-Control. Calcium was not significantly decreased by the NTC-FeCl and NTC-PACL treatments. Significant calcium differences were found for STC-PACL, but close examination of the results suggested that differences may have been attributable as much to small sample size as to a real effect. The models predicted the observed concentrations very well, and so very small statistical differences were detectable. Aluminum concentrations did not present a linear pattern and the results were difficult to interpret using PWA. A visual inspection of the data showed that total aluminum concentrations (the analyzed parameter) were clearly increased by the treatments. Magnesium showed no significant change. NTC-FeCl chloride concentrations were significantly (60 percent) elevated, but only slightly (20 percent) in NTC-PACL. The south cell treatment changed chloride concentrations insignificantly in the STC-PACL.

ES.4.4 Evaluation of Marsh Readiness

Marsh readiness refers to the ensemble water quality characteristics of the water leaving the treatment wetland and the chemical similarity of that water to receiving waters. The concern is whether chemically treated waters are "marsh ready," that is of acceptable quality to be discharged to the marshes of the Everglades ecosystem. A goal of the testing at the ENR was to characterize the effects of chemical treatment on the post-Best Management Practice (BMP) and post-Stormwater Treatment Area (STA) waters and then to examine the effect of wetland cell on chemical changes induced by the treatment.

The marsh readiness of water from the test cells was evaluated by visual inspection of ionic parameters presented using Schoeller plots and radial plots. Pretreatment period parameter value averages were compared to treatment period parameter values for the NTCs and STCs, and available water quality data for the Water Conservation Areas (WCAs).

In both the calibration and treatment periods, little change in concentrations were seen in calcium, magnesium, sulfate, TDS, and TOC. During the calibration and treatment period, NTC-FeCl and NTC-PACL showed an increase in aluminum at the first (1/3) station, but aluminum concentrations dropped off after this station in NTC-PACL. STC-Control and STC-PACL were exporting aluminum during the calibration period. Aluminum levels were reduced by the marsh in STC-PACL during the treatment period.

NTC-FeCl, NTC-PACL, STC-Control, and STC-PACL appeared to be exporting iron at the 1/3 station during the calibration period. This trend continued during the treatment period in NTC-Control, NTC-PACL, STC-Control, and STC-PACL. Iron concentrations were at a maximum in the plant outflow and outflow of NTC-FeCl during the treatment period. There was a clear drop in iron concentrations as water flowed through the NTC-FeCl wetland.

Iron and aluminum treatments reduced alkalinity concentrations, but the concentrations in the marsh were stabilized after the 1/3 station. The pH level in all treatment cells (NTC-FeC1, NTC-PACL, STC-PACL) also remained stable through the marsh after the 1/3 station. Both NTC-FeCl and NTC-PACL treatments caused increases in total chloride concentrations in the plant outflow. The increase was likely associated with floc overflowing the plants, which settled out in the marsh.

Total phosphorous concentrations averaged over the entire treatment period were highest at the 1/3 station in NTC-Control, NTC-PACL, STC-Control and STC-PACL. The lowest average concentrations were at the wetlands outflow. With the exception of NTC-Control, total dissolved phosphorous concentrations were not affected by the marsh. TDP in NTC-Control increased between the inflow and the one-third station. The marsh did not have a significant impact on SRP levels in NTC-FeC1, NTC-PACL, or STC-Control, but concentrations did drop significantly in NTC-Control and STC-PACL. NTC and STC treatments (NTC-FeCl and PACL) reduced TN values relative to their respective controls. At the NTCs, the PACL treatment reduced nitrogen to greater extent than did FeCl.

A comparison of the test cell data with data from the WCAs is a useful method of extending the comparison to consider the question of overall “marsh readiness” of the water. Comparisons between the WCAs show that constituent concentrations differ between the respective conservation areas. Comparison of the MWTS test cells treatment period data with WCA data suggests that the ionic condition of the test cells’ outflow is very similar to that found in the interior of WCA 2. The exception is NTC-FeCl, the iron treatment cell.

ES.5 Verification Tests

A variety of tests were performed on the water column, soils, and sludge to evaluate effects of the MWTS on the ecosystem:

- Laboratory bio-toxicity testing used a fish species, an invertebrate organism and a green alga to evaluate potential toxicity due to iron or aluminum chemicals used in the treatment process or other, unknown, process that might have resulted in toxic conditions.

- Algal Growth Potential (AGP) tested the bioavailabililty of nutrients in wetlands outflow samples from each of the cells (NTC-FeCl, NTC-Control, NTC-PACL, STC-Control, and STC-PACL).
- Leaching tests Toxicity Characteristic Leaching Procedure (TCLP) were performed on the sludge to assess the potential of chemicals to re-release PACL and FeCl.
- Soil tests measured changes in the amounts of target elements (nutrients, metals, minerals) in the surface soils at the beginning and end of the experiments.

These procedures followed the FDEP Phase I testing Protocol/Process verification testing described in their guidance document on the subject.

Toxicity Tests

Toxicity testing was inconclusive.

Algal Growth Potential (AGP)

There was not significant growth potential found with the AGP test. All maximum standing crop values for NTC-FeCl, NTC-Control, NTC-PACL, STC-Control, and STC-PACL were significantly below that of the laboratory controls.

Toxicity Characteristic Leaching Procedure (TCLP)

Sludge samples collected from the solids separator/storage tanks for each chemical treatment plant (NTC-FeCl, NTC-PACL, and STC-PACL) were tested for potential leaching. The leachate was well below federal statutory limits for all chemicals (there are no Florida state statutory limits for the TCLP).

Soil Tests

Soil samples were collected twice during the calibration period and twice (at the beginning and end of) the treatment period (March and December 2000). Tests for total aluminum, iron, and phosphorous showed considerable initial variation between cells. Total aluminum soil burdens (µg Al/g dry soil) from NTC-PACL and STC-PACL made during the treatment period were slightly lower than those during the calibration period. Iron burdens rose slightly in NTC-FeCl (27 µg/g dry soil). The results suggest that there was little metal deposition during the test period. However, the sample size was very small. Phosphorous burdens were highest in the March 2000 samples, but varied enormously both in time and by cell. No clear conclusions could be drawn from the data. The sample results suggest that many more samples would have been needed to provide a statistically rigorous result.

ES.6 Summary

The MWTS testing program was designed to simulate the performance of a pond-based chemical treatment system with in-pipe injection of flocculating chemicals followed by discharge to a floc settling pond with a long retention time. A treatment wetland would receive the outflow from the pond for final water quality polishing and protection. The experimental system, as operated, included a chemical plant that injected and mixed the chemicals with the inflow water, settling and storage components, with a release from the storage tank to the wetland. The operation of this treatment system then sought to verify three treatment effects:

1) TP reduction to very low levels, as has been demonstrated in the Chemical Treatment/ Solids Separation (CT/SS) project.

2) The wetland system would act as a polishing filter, and as a water quality conditioner, ameliorating the chemical changes induced by the chemical treatment.

3) Settled solids could remain in contact with the treated water without bleeding P back into the water column.

The experimental design included a hydraulic loading rate that would result in full-scale design with a reasonable wetland space requirement. The chemical plant's clarifier and sludge storage tanks did not completely capture the floc due to operational and design constraints. With the wetlands performing a solids capture function, the experiment as actually performed provided results for a chemical treatment – settling pond – wetland system with periodic floc overflow. The solids management problems encountered with the treatment units at the ENR can be overcome with a pond-based treatment system. The treatment pond concept was to be tested in Phase 2 of the project; however, Phase 2 work was not completed. A brief summary of operational results from Phase 1 is as follows:

- Chemical treatment can reduce P to, or very close to, target concentrations.
- PACL and FeCl reduced TP concentrations approximately equally.
- No re-dissolution of phosphorous from settled solids was detected. This verified that a pond-based treatment system sized for solids storage would provide effective P removal.
- Floc overflow (not unknown, even expected as an occasional accidental event in the wastewater industry) occurred and was controlled by the treatment marsh, thus protecting receiving waters beyond the marsh outflow.
- Elevated PACL concentrations were found in the marsh outflow of the NTC-PACL treatment cell, but the high concentrations in the treatment plant outflow were greatly reduced during passage through the marsh. Iron increases in the FeCl plant outflow were similarly reduced.
- The marsh provided ionic conditioning, changing the alkalinity, hardness, aluminum, and iron concentrations toward inflow values as the water flowed through the marsh.
- The sludge by-product was found non-hazardous by standard testing procedures.
- There was no apparent bio-toxicity associated with the outflow waters, although test results were not conclusive in indicating that there were absolutely no potential problems.

The MWTS system had floc overflow far in excess of what a full-scale engineered system would produce. The fact that the experimental chemical plant did not fully sequester the floc does not suggest that the full-scale system cannot be built, but only that the originally equipment configuration test should be re-designed. The rate and amount of solids overflow was influenced by four factors: 1) the relatively high flow rate, 2) high coagulant dosages that were increased in response to erroneous laboratory data, 3) sludge recirculation during periods of high coagulant dosing, and 4) resuspension of settled solids in the sludge storage tank whenever solids were transferred to the tank. An important finding of this study is that the combined chemical and wetland treatment system performed effectively in maintaining appropriate outflow conditions under worst case plant operating conditions. This experiment is not intended to suggest that this is how a chemical treatment plant ought to be operated, or that wetlands should be continually loaded with aluminum or iron flocs. This experiment did indicate that a wetland can function to condition the water after treatment, and suggested that periodic operational accidents can be managed safely in such a system. These design and operational problems can be overcome with a pond that provides treatment, settling, and solids storage.

The District, with the concurrence of the SAC, decided not to undertake the second phase of this project, which would have involved a field scale test of a pond-based chemical treatment system. The Seminole Indian Tribe decided not to continue the cooperative agreement under which the second phase of the project was to be conducted.